CHEMISTRY

IN THE

UNITED STATES DEPARTMENT *of* AGRICULTURE

WASHINGTON
U. S. DEPARTMENT OF AGRICULTURE

SEPTEMBER, 1927

U. S. GOVERNMENT PRINTING OFFICE : 1927

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

September, 1927

Secretary of Agriculture	W. M. JARDINE.
Assistant Secretary	R. W. DUNLAP.
Director of Scientific Work	A. F. WOODS.
Director of Regulatory Work	WALTER G. CAMPBELL.
Direction of Extension	C. W. WARBURTON.
Director of Personnel and Business Administration.	W. W. STOCKBERGER.
Director of Information	NELSON ANTRIM CRAWFORD.
Solicitor	R. W. WILLIAMS.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Dairy Industry	C. W. LARSON, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	W. B. GREELEY, *Chief.*
Bureau of Chemistry and Soils	C. A. BROWNE, *Acting Chief.*
Bureau of Entomology	L. O. HOWARD, *Chief.*
Bureau of Biological Survey	PAUL G. REDINGTON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Bureau of Agricultural Economics	LLOYD S. TENNY, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Federal Horticultural Board	C. L. MARLATT, *Chairman.*
Grain Futures Administration	J. W. T. DUVEL, *Chief.*
Food, Drug, and Insecticide Administration.	WALTER G. CAMPBELL, *Director of Regulatory Work, in Charge.*
Office of Experiment Stations	E. W. ALLEN, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*

CHEMISTRY IN THE UNITED STATES DEPARTMENT OF AGRICULTURE

FOREWORD

Without the assistance of chemistry it is quite possible that modern agriculture would be little ahead of the crop and animal growing practices in use 300 years ago. To be sure, some progress was made with only the most superficial knowledge of the parts played by the principal elements, but the development of chemistry was needed to put empirical practices on an understandable basis and open the way for sure and steady improvement in the feeding of both plants and animals and a host of other problems touching agriculture directly and indirectly. Since its establishment in 1862, the United States Department of Agriculture has been interested in chemical work; in fact, from the very beginning, there was a division of chemistry, with a staff of four or five men. It finally developed into a bureau, and in a reorganization effective July 1, 1927, was consolidated with the Bureau of Soils, the fixed-nitrogen research laboratory, and a section of the Bureau of Plant Industry to form the Bureau of Chemistry and Soils. It now concerns itself with problems not even on the horizon of its experience 50 years ago. Not only this bureau but 8 or 10 others of the department now depend upon chemists in small or great degree to apply their solvents to obstacles in the way of better living conditions. The problems not only of agriculture but a thousand and one others, of the consumer and the manufacturer, are attacked. In other words, the department's concern is not limited to farm products while they are still on the farm, but follows them to their destination. Furthermore, it is concerned with agricultural materials even before they reach the farm.

A few examples will indicate the scope of the activities based on chemistry. Sources of fertilizer are

61211—27——1

investigated and processes of manufacture are developed to provide better and cheaper materials for crop production. Materials offered by manufacturers for the control of diseases and pests are tested in order that the prospective user may not be defrauded. Better methods of making and handling dairy products are originated and introduced. Investigations are made to find processes for putting up new fruits and vegetables or to develop better methods for preserving well-known products. Manufacturers have been given more effective ways for making sirup, paper, and dyes and for preparing leather, and equipment has been designed to protect many industries from dust explosions. The medical profession has been provided with better means for fighting some widespread and destructive diseases. Efforts are being made to find the composition of the natural plant odors which attract insects, a possible way to fight pests. Lures for attracting predatory animals have been discovered and used. New facts about vitamins have been brought to light, and there have been recent revelations regarding the fundamental make-up of soils.

In the Department of Agriculture the chemist is tilling many productive fields, and new discoveries are continually opening other opportunities where he may be of greater service to people engaged in all sorts of activities. The chemical work being done by various branches of the department is described briefly in the following pages.

BUREAU OF CHEMISTRY AND SOILS

The Bureau of Chemistry and Soils studies chemical problems pertaining to agriculture and to industries which utilize agricultural products. Some of its investigational activities, which fall into the following groups, may be noted particularly.

Carbohydrates

The carbohydrate division seeks to promote by chemical investigation the more effective production and utilization of sugar-producing crops. Attention is given to various carbohydrate products, such as cane

and beet sugar, cane and sorghum sirups, maple products, corn sugar, corn sirup, starches, starch conversion products, and honey.

In connection with these carbohydrate investigations, considerable attention is being given to a study of the colloids in plant juices and to methods for their approximate quantitative estimation. It is now known that the removal of colloidal material is an important feature of processes for clarifying cane and beet juices and starch conversion liquors before crystallization of sugar. Recent investigations in this laboratory have shown that the poor refining quality of certain raw sugars is due not only to salts but to colloids, which are present both in the sugar crystals and in the liquid film enveloping them.

Methods of controlling clarification of beet and cane juice have been studied, and means are being developed whereby this extremely important process may be governed automatically. The operation is based on the hydrogen-ion concentration of the treated juice, since the hydrogen-ion concentration is a determining factor in clarification and subsequent factory operation. Investigations have led to the conclusion that impurities are responsible for variations in the quality of commercial granulated sugar. The nature of the impurities which have detrimental effects, and methods whereby they may be eliminated during manufacture are receiving attention.

Owing to certain unfavorable cultural conditions existing in the sugar cane section of the United States, a situation of economic importance has arisen. It will be of assistance to this industry if attention be given to the development of specialties in addition to standard products, such as sugar and sirup. With this situation in mind, a new product, called "cane cream," is being developed. It is a delicious spread for bread, biscuits, and waffles. Possibilities of the production of other specialties will be studied as opportunity is presented, in order to assist in diversifying sugar cane products and to enhance the value of the sugar-producing crop.

In addition to the many practical problems investigated, fundamental research pertaining to rare sugars and sugar derivatives and to methods of sugar analysis is undertaken.

Crop Chemistry

The effect of added inorganic plant food constituents on the chemical composition of crop plants is studied with the purpose of increasing the content of protein and other valuable components in crops. It has thus far been possible to obtain a substantial increase of protein in wheat and in rye. Moreover, the high-protein wheat obtained in our experiments has yielded flour of superior baking qualities. Special attention is being given to the interrelation of soil acidity and crop plants, and to the effect of applying various fertilizers at different stages of growth of the plants. In this connection studies are made of the fundamental principles governing absorption of food by plants and of the relation of soil reaction to the growth of native plants. Analytical methods, both for constituents of the ash of plants and for acidity determination, are studied, and improved upon if possible.

Crystallography

Crystalline substances are immersed in liquids of known refractive index and studied under the polarizing microscope; and data are obtained of value for identification purposes. Crystallographic and optical constants are determined for new and unusual compounds prepared by members of the department staff, and are placed on record along with other physical and chemical constants.

Dust Explosions and Farm Fires

The heavy loss of life and property from dust explosions and fires in threshing machines, grain elevators, cotton gins, flour mills, starch mills, cottonseed-oil mills, and in other manufacturing plants led to an extensive study of methods for preventing such disasters. Through its field work and laboratory tests the bureau has devised and perfected appliances and proposed modifications of existing practices and procedures which have been helpful in reducing the explosion hazard in the dusty industries.

Fires on the farm and in the rural community cause large loss of life and property. One of the main problems being studied by the bureau on the new project of farm fire prevention is that of the spontaneous combustion of hay, grain, feeds, and other agricultural products.

Dyes

The work on dyes has proceeded along the two lines of intermediates and biological stains. An attempt is being made to develop new intermediates for vat dyes through the combination of phthalic anhydride with other compounds by means of the Friedel-Craft synthesis, and it is proposed to make a thorough study of the possibilities of this process. Biological stains, although insignificant from the aspect of total pounds produced, are of the utmost importance to many lines of research and practice, both medicinal and biological. The work on these materials has progressed along the dual lines of standardization and improvement, with studies of the physical and chemical characteristics of many of the well-known stains. In this work the spectrophotometer has proved of incalculable value; many difficult problems have been solved by its use.

Industrial Wastes

One laboratory is devoted to finding uses for various industrial wastes, particularly those produced in the chemical industry. Results obtained recently on paracymene and o-dichlorobenzene point to the possible utilization of these materials in ways not yet attempted. A study of the coal-tar acids obtained in the low temperature distillation of bituminous coal is in progress, with a view to determining the nature and potentialities of these complex materials.

Farm Wastes

Special attention is being paid to many of the agricultural wastes. At present peanut hulls are the subject of investigation. It is hoped that use may be found for the pulp, which is of good quality, though

short in fiber. The question of the fermentation of the water-soluble material is being considered also.

Lignin, which is an important constituent of all farm wastes, has in it great possibilities as a raw material for organic synthesis. A fundamental research on its composition and structure has been undertaken.

Fermentation

Industrial fermentations are yearly assuming more importance in chemical industry. This laboratory has undertaken a study of the action of molds in the production of organic acids from dextrose. Good yields of gluconic acid have already been obtained, and the development of industrial uses for this acid are contemplated.

Food Research

The food research division is engaged in a fundamental examination of foodstuffs in all phases of their development, from raw materials to the finished products. The division is organized to attack food problems from the standpoints of the chemist, the mycologist, the bacteriologist, the microscopist, and the economist. It collaborates with the organizations which are dealing with specific food constituents, such as carbohydrates, oils, and fats, and proteins. Food problems are studied both in the laboratory and in the field in close contact with the large-scale producers. By this means much useful information is made readily accessible to the public.

Fruit and Vegetable Chemistry

These investigations are concerned with: The determination of organic acids and other chemical components contained in fresh and preserved fruits and vegetables, and in various products derived from them, such as fruit juices and jellies; the economical utilization of fruit and vegetable culls; various methods of preserving fruits and vegetables by drying, by chemical treatments, and by other recognized processes; utilization of cannery wastes; and means for improving the natural color of fruits, vegetables, and their products.

Metals in Foods

This subject is interpreted for the present to comprise all substances which are not usually understood to be normal constituents of cellular tissue as well as those which may be added in excessive quantities to foods during the process of preparation. Chemical studies are in progress to detect and, when possible, to estimate the normal as well as excessive quantities of chemical elements in all forms of food.

In addition to food work, this laboratory tests the quality of all reagent chemicals purchased by the bureau, to ascertain whether they comply with the specifications under which they are bought. A similar service is rendered by this laboratory to the food, drug and insecticide administration. In the nitrogen laboratory, nitrogen determinations are made on all sorts of samples, not only for this bureau but for all chemical laboratories of the department which are not provided with the equipment for this work.

Microbiological Investigations

Chemical examinations alone of food products are not adequate. These must be supplemented or, when necessary, superseded, by microbiological examinations. Many problems arise constantly concerning the decomposition of raw foods and the keeping qualities of canned goods, for example, possible contamination of foods by thermophilic or other bacteria during canning; deterioration of raw sugar and other foods in storage; and fermentation due to yeasts in fondants and marshmallow sirups. The biological factors related to the heating of farm products, and the application of lactic and acetic acid-forming bacteria in pickle and vinegar fermentation are other subjects of investigation. Viable cultures of fungi of importance to agriculture, industry, and science are maintained in the collections of the division and in the American-type culture collection supervised by the department.

Food Microscopy

Histological and microchemical studies of the structure and composition of fruits, vegetables, and grains are made, as a basis for calculating normal and

abnormal constituents in their manufactured products, and also for determining the causes of different behavior under varying conditions of manufacture.

Insecticides

Derivatives of the dipyridyls are prepared in the insecticide division; and their toxicity upon aphids is tested by the Bureau of Entomology. Certain compounds of high insecticidal efficacy have been synthesized for the first time, and there is an excellent prospect of developing from these compounds a commercial process for making a contact insecticide which exceeds even nicotine in toxicity. Methods for the synthesis of nicotine are being studied.

Factors influencing the toxicity of hydrocyanic acid gas to insects under greenhouse fumigating conditions are investigated. Dosages of hydrocyanic acid much smaller than those hitherto recommended have been found effective in controlling certain insects in greenhouses. A statistical study of the results of cyanide fumigation is in progress. The rate of vaporization of carbon disulphide has been studied, and an apparatus has been devised for its rapid volatilization. The efficacy of naphthalene vapor as a fumigant is being tested.

New fumigants of low fire hazard are developed to take the place of the dangerous carbon disulphide. When used in commercial fumigating vaults, a mixture of ethylene dichloride and carbon tetrachloride has been found effective in killing clothes moths, carpet beetles, and other insects infesting stored products. This mixture has a pleasant odor, is nonburnable, relatively nontoxic to man, and is cheap. It is confidently believed that this new fumigant will be eagerly welcomed by warehousemen. The Bureau of Entomology is cooperating in this investigation.

Investigations of repellents and attractants for flies are being continued, in collaboration with the Bureau of Entomology. It has been found that the response of flies to certain compounds is influenced by the concentration of the compound. For example, a large quantity of bergamot oil spread upon meat repels flies, whereas a small quantity enhances the

natural attractiveness of the meat. We have found also that certain inodorous compounds, such as copper carbonate, are more effective in repelling flies from meat than any of the highly odorous compounds tested. These investigations have thrown light on the difficult problem of insect chemotropism.

The work of the insecticide division has resulted in the use of pine-tar oil as a repellent dressing for wounds on domestic animals. Large manufacturers of proprietary screw-worm killers and repellents are now using pine-tar oil as the basis of their preparations instead of the injurious coal-tar phenols formerly used.

Leather and Tanning Investigations

The effect of the various tannages and manufacturing processes upon the quality and serviceability of leathers is studied. The chemical and physical properties of leather are correlated with the service it gives, and the cause and prevention of deterioration of leather articles are investigated. Other research in this field deals with the relative value of leather and leather substitutes; the requirements for leathers designed for special purposes, as, for example, bookbinding leathers; new sources of vegetable and mineral tanning materials; improvement in the quality of hides and skins; and utilization of tannery and leather wastes. In collaboration with interested scientific societies, improved methods for the examination of leather and tanning materials are developed.

Naval Stores

Researches on the properties and uses of pine-tree products, and investigations on the methods of producing, handling, and grading rosin and turpentine are conducted to help the industry. Improved methods of producing turpentine and rosin are demonstrated in the field. Statistics on consumption and available stocks of turpentine are compiled and published annually.

61211—27——2

Oil, Fat, and Wax

Progress in the fat and oil industries has been hampered by the lack of knowledge of the major and minor constituents of many of the vegetable oils. Accordingly, the bureau determines and publishes the chemical composition of these substances. Vegetable oils from new sources are examined to discover the purposes they may serve and whether or not it is feasible to produce them commercially. Methods are devised or improved for the investigation of various oils and the products made from them. New derivatives of the higher fatty acids are prepared, and their chemical and physical properties are determined to ascertain whether or not any of these compounds may serve for the quantitative separation of any of the higher fatty acids from each other. Also, various types of glycerides are being studied to get a more intimate knowledge of their properties. Because of the yearly loss, running into thousands of dollars, suffered by crude oil millers who are forced to hold their stock for a considerable length of time, the keeping quality of various oils is being investigated, to determine under what conditions the crude oil may be stored with the minimum deterioriation.

Paper

The factors and qualities which fix the serviceability and durability of paper, and methods for detecting these qualities, are investigated, with a view to developing the more economical and effective use of paper and conserving papermaking raw materials. Means of preventing the rapid deterioration of unexposed brown print paper have recently been made public. Special attention is given to permanent-record, blue-print, fruit-wrapping, and bale-wrapping papers, and to fiber and corrugated board. An impact tester has been designed and built to obtain information on the probable durability of fiber board. New methods for testing paper are worked out from time to time, primarily to enable analysts to pass upon samples of the many kinds of paper used by the Government.

Proteins and Nutrition

The nutritive value of the proteins in foodstuffs depends chiefly upon their content of the nutritionally essential amino acids. As some proteins lack the essential amino acids, the chemical composition as well as the quantity of protein is important. Accordingly, proteins from various sources are isolated in pure condition, their properties are studied, and their content of amino acid is determined. This work has shown how certain feeding stuffs, the proteins of which have a low nutritional value owing to their amino acid deficiency, can be used satisfactorily by adding feeding stuffs containing these amino acids in abundance, so that the mixture will contain sufficient of all the amino acids necessary for the normal nutrition of animals, The proteins of certain seeds and plants not yet used for food are studied, to ascertain their potential food value. These chemical studies are supplemented by feeding experiments with small animals. Fundamental research work is also being done to devise methods for the isolation and properties of proteins and amino acids. Certain fractions of the proteins of pollen have been investigated in connection with their relation to hay fever. Comprehensive studies are in progress to determine the vitamin content of certain shell fish, such as oysters and clams, and also to ascertain the food value of their proteins. Work is done also to determine the vitamin potency of various foods and drugs, in order to secure information for the guidance of officials in the enforcement of the Federal food and drugs act.

Waterproofing and Preserving Fabrics

Simple directions for effective waterproofing and mildew-proofing treatments for canvas, that may be easily and cheaply followed, have been formulated in the bureau. Work on weather-resistant fire-proofing treatments for canvas is in progress; light-resistant treatments for tobacco shade cloth have been devised and demonstrated. It has been shown that sunlight is the most important agency in the deterioration of treated fabrics exposed to the weather and that the

addition of certain pigments to waterproofing materials goes far in protecting fabrics from injury by sunlight. Practical methods for testing water and mildew resistance have been developed.

Fertilizer and Fixed-Nitrogen Investigations

The nitrogen-fixation investigations carried on by the fixed-nitrogen research laboratory have been combined with the work of the Bureau of Soils on phosphates, potash, and concentrated fertilizers to form the fertilizer and fixed-nitrogen unit of the Bureau of Chemistry and Soils. These investigations have for their object the discovery and development of processes capable of furnishing cheaper and more efficient fertilizers and fertilizer materials.

Having performed a useful service in aiding the establishment of a synthetic ammonia industry in the United States, this unit is now giving increased attention to fundamental studies on the nature of catalyst surfaces and on the mechanism of their action in promoting gas reactions. Investigations are under way dealing with the rate of formation and decomposition of ammonia; the production of hydrogen from water gas and steam as a function of velocity, temperature, and composition of gas mixture; the crystal structure and thermionic properties of catalysts and catalyst materials; and the effect of contact poisons and promoters on the extent and activity of surfaces.

Numerous technical problems in the production of hydrogen and ammonia are also under investigation. Important projects are: The development and testing of more efficient and stable catalysts, especially for the reaction between water-gas and steam; the removal from hydrogen of impurities, carbon monoxide by selective oxidation, and methane by absorption in suitable solvents under pressure; and a study of the effect of temperature gradients in catalyst beds during operation.

An extensive program of research is being pursued on the properties of hydrogen, nitrogen, and other gases of industrial importance at pressures up to 1,000 atmospheres and at temperatures up to 400° C.

Extensive efforts have been devoted to studies on the composition of compressed gases in contact with liquids. The data so obtained furnish the fundamentals on which much of the design of high-pressure equipment must be based. The highest accuracy is sought in this work, in order that the results may at the same time contribute to a clearer understanding of the nature of the gaseous and liquid states.

Considerable attention is being devoted to an effort to learn the secrets of nitrogen fixation by bacteria. Both the symbiotic and the free-living types of organism are being investigated, with the object of discovering the intermediate steps by which the free nitrogen of the atmosphere is converted into protein. A closely related problem is concerned with the availability of ammonia nitrogen to various types of plants when bacteria are completely excluded. Certain classes of organic nitrogen compounds are being studied, with a view to bringing free nitrogen into combination at ordinary temperatures and pressures without the aid of living organisms.

Investigations have been completed on a number of other methods of fixing nitrogen. Among these are the formation of aluminum nitride, calcium cyanamide, and sodium cyanide, and the production of nitric oxide as a by-product in the explosion of carbon monoxide-air mixtures.

One of the most important problems with which the unit is concerned is the transformation of the primary products of nitrogen fixation processes into suitable fertilizers. Ammonia or nitric acid must be combined with a suitable carrier, preferably itself a fertilizer. Much effort has been focused on the production of urea from ammonia and carbon dioxide, since its availability to plants, high nitrogen content, and desirable physical properties make this material one of the most promising transformation products of ammonia. The problems that arise in connection with this work are being attacked both in the laboratory and in an experimental plant, and data are obtained to facilitate the design of commercial plants.

In the oxidation of ammonia to nitric acid, an attempt is being made to substitute base-metal catalysts

for the platinum commonly employed and to carry out the reaction with oxygen rather than air, in order to facilitate absorption of the nitrogen oxides formed or to obtain the product in the form of liquid nitrogen tetroxide. This liquid has been studied with a view to its utilization in the direct nitration of organic compounds and in the production of nitrogenous fertilizers by absorption in various carriers.

In addition to projects dealing with fixation and utilization of nitrogen, attention is directed to the other essential fertilizer constituents, particularly phosphorus and potassium. Since superphosphate is unsatisfactory as a carrier for ammonia because under these conditions it reverts to the insoluble form, intensive studies are being pursued, with a view to the conversion of phosphate rock into liquid phosphoric acid and finally ammonium or potassium phosphate. The results of the investigations on the volatilization of phosphoric acid have led to the development of two commercial processes. The electric furnace process has been in commercial operation for about six years, and now produces about 75 per cent of the phosphoric acid used in this country for the manufacture of food products and for industrial purposes. The fuel-fired furnace process has been subjected to intensive investigation on a semicommercial scale during the past three years, and undoubtedly steps will be taken soon toward putting the process into large scale commercial operation.

An extensive series of investigations is now being made of the fundamental reactions that take place in the volatilization of phosphoric acid when phosphate rock is smelted in the presence of carbon or carbon monoxide, with or without the addition of sand or natural silicate. A survey has been undertaken of the fluorine content of phosphate rock and other phosphatic materials from widely separated sources.

Much attention has been given to possible sources of potash in this country and to methods for their utilization. As a result of explorations conducted partly in cooperation with the United States Geological Survey, a number of salt deposits and brines, particularly in the arid regions, have been discovered to be potential sources of potash. Searle's Lake, Calif., now

yields 20 per cent of the potash requirements of the United States. Numerous other sources have been investigated, such as cement and blast-furnace dusts, distillery and beet-sugar wastes, and the giant kelps of the Pacific coast; and, when feasible, large scale experiments on them have been conducted.

In order that potash may be produced economically from such materials, it is essential that by-products be utilized to share the costs of extraction. Particular emphasis is being placed on this phase of the problem. Thus, a decolorizing carbon (kelp char) and iodine have been produced as by-products from kelp; and in the process recently developed for the extraction of potash from greensand, the largest potential source so far discovered in this country, several by-products of economic importance are obtained, including ferric oxide, alum, alumina, ammonium sulfate, and glaucosil, an active adsorbent silica.

Methods are being studied and developed for the utilization of phosphoric acid in conjunction with potassium chloride or ammonia to produce the so-called concentrated fertilizers, from which inert material is largely or wholly eliminated. Particular attention is being devoted to the reaction of phosphoric acid to potassium chloride, and the interaction of each of these materials with ammonia and with nitrogen peroxide to form two-constituent fertilizer materials, such as ammonium phosphate, potassium phosphate, and potassium nitrate. These substances offer the advantage that they are among the least hygroscopic of soluble materials, and a mixture of any two of them furnishes a complete, concentrated fertilizer.

Another phase of the fertilizer work requires a study of the chemical and physical properties and of the storage qualities of fertilizer materials and mixtures. The chief problem in this connection concerns the hygroscopic nature of many materials, otherwise excellent, prepared from synthetic ammonia, and means for combatting this objectionable property.

The usefulness for fertilizer purposes of waste organic materials and by-products, and methods for converting such materials into desirable forms, are investigated. Efforts are being made to improve the processes used

in the production of organic ammoniates; and miscellaneous materials used as soil amendments, such as sulfur and lime, are receiving attention.

Soil Investigations

Soil-fertility investigations necessitate basic chemical research, including chemical analysis of soils, and determination of phosphate, potash, nitrogen, and lime requirements, and soil reaction. Studies are made of the changes that take place in plants in the course of a season and in a series of years. Different systems of fertilization are tried on different types of soil, the effect on both soil fertility and the quality of the crops being noted. These experiments require mineral analyses, and, in addition, determination of fats, proteins, starches, sugars, and other organic constituents which determine the quality of crops.

The organic constituents of the complex humus of the soil are isolated, and their origin and transformation in soils as well as their physiological effects on plants are investigated. Also the effect of borax, manganese, and other rare soil substances on plant nutrition is made the subject of investigation.

Since fertilizers influence the intensity of the green color of plant foliage, color is taken as a basis for ascertaining the nitrogen, potash, or phosphate hunger of plants. A chemical study of the green and yellow plant pigments is under way, with a view to measuring them quantitatively and bringing them under definite chemical control.

The many new nitrogen compounds, both organic and inorganic, now being introduced into the fertilizer trade as a result of the fixation of atmospheric nitrogen, bring new problems of soil fertility, which must be solved by chemically controlled experiments. Special attention is being given to the effects on soil and crops of the more compact fertilizers now made possible by these highly concentrated plant foods. Their chemical transformation and their effect on soils are studied in the laboratory; their physiological properties are observed in the greenhouse and in the field.

An extensive system of field experiments with fertilizer salts to discover the best formulas for use in

practical agriculture is in operation in more than 50 localities with widely different kinds of soil and crops. The thousands of different fertilizer mixtures tested in this manner are prepared under strict chemical control.

The reaction of soils and its relation to plant diseases is receiving attention.

The properties and chemical composition of soil samples are studied in connection with the classification and mapping of soils. Investigations are conducted on: Methods of analysis; the nature and properties of different parts of the soil, particularly colloidal material; the chemical and minerological changes that take place in the soil as it develops; the influence of different soil constitutuents on absorption; the development of acidity; and the effectiveness of phosphatic fertilizers. Analytical, physicochemical, and petrographic methods are used.

A study of the chemical changes resulting from the activities of bacteria and molds in the soil is carried on parallel with a study of the organisms themselves. Chemical studies of the decomposition of organic matter, nitrate formation, nitrogen fixation, and acidification are closely correlated with studies of the organisms active in these processes.

Soil Survey

To obtain more accurate knowledge of the soils of the United States and to obtain data for use in soil classification and mapping, hydrogen-ion determinations are made of samples representing the more important types of soil of different horizons. The laboratory is equipped for accurately determining the hydrogen-ion concentration by the most approved electrometric and colorimetric methods.

In addition to these various chemical research activities, simple chemical tests are made on soil samples which farmers send to the bureau for aid in solving practical soil-management problems.

61211—27——3

BUREAU OF AGRICULTURAL ECONOMICS

Chemical activities of the Bureau of Agricultural Economics are confined largely to the grain division. Here a well-equipped chemical research laboratory and a milling and baking laboratory are maintained for the purpose of accumulating data necessary for the preparation and enforcement of the United States grading standards for cereal grains and flaxseed. Methods for grading grain are developed and perfected, so that the various grading factors can be efficiently determined; and special problems that arise in connection with the enforcement of the United States grain standards act are studied. Other chemical activities of the bureau are: Milling and baking studies; protein investigations; rapid oil tests; moisture investigations; farm storage investigations; and special laboratory tests.

Milling and Baking Studies

Every crop year many samples of wheat, representing the various commercial classes, are collected, milled, and baked, and compared with samples from other crops. Not only is the quality noted, but also whether the usual grading factors reflect the quality of the wheat. Special milling experiments aimed to study the best methods and conditions for valuating wheats and flour are conducted. The best grades and types of flour for different kinds of baked goods are determined by baking experiments.

Protein Investigations

Since the grain trade buys wheat on a protein basis, investigations are in progress with a view to the standardization of the Kjeldahl test for making nitrogen determinations, in order that a uniform test may be available. Experiments are conducted also for the purpose of studying the factors which contribute to gluten quality.

Rapid Oil Tests

Methods for rapidly determining the oil content of seeds are devised. Methods are being developed for cottonseed, cottonseed meal, cocoa beans, chip liquors, peanuts, soy beans, sesame seed, and flaxseed.

Moisture Investigations

To aid the grain trade in making moisture tests on whole grains and seed, the methods, technique, and apparatus necessary for such tests are given careful attention.

Farm Storage and Special Laboratory Investigations

The physical, chemical, and biological processes which take place in wheat stored on the farm are investigated. Methods for determining the ash, color, moisture, and enzymic and protein complex of wheat and wheat flours are perfected for use in studying related problems.

BUREAU OF ANIMAL INDUSTRY

Chemistry plays a part in practically all the varied activites of the Bureau of Animal Industry in connection with its extensive control work in the fields of meat inspection; tick eradication, scabies eradication, and tuberculosis eradication; virus and serum inspection; and the control of animal diseases through regulation of interstate traffic. Chemists are employed and laboratories are maintained for the purpose of insuring the purity of meats and the purity and potency of viruses and antitoxins prepared under Federal inspection. Chemists of the bureau likewise supervise the physical and chemical composition and the field and laboratory testing of arsenical, lime and sulphur, and nicotine dips, as well as of disinfectants used in stock yards, stock cars, and for other official purposes.

In addition to control work, chemistry is used in a variety of research work. The chemical composition

and nutritive value of various meats and meat products are studied. Changes, such as rancidity in animal fats, are investigated, and efforts are made to devise methods for preventing spoilage. Chemical studies in animal nutrition involving studies of the effect of food not only on animals but on animal products, such as soft pork, are pursued extensively. Biochemical investigations of bacteria and bacterial products, particularly *B.* tuberculosis and tuberculin, are carried on, as are chemical investigations of vermifuges and insecticides. Chemical and bacteriological studies of dips and disinfectants are made, with the idea of improving the present methods. Attention is given the effect of disinfectants on hides and tannery wastes. In determining the effect of injurious plants on animals, the plants themselves are studied, with the object of isolating and identifying the constituents which are responsible for injury to livestock.

BUREAU OF DAIRYING

The Bureau of Dairying makes use of chemistry chiefly in its investigations on the nutrition of dairy cows and the secretion of milk. It uses chemistry also in studies on bacteria, the chemico-physical properties of milk, and the utilization of dairy by-products.

Nutrition of Dairy Cows and Secretion of Milk

A comprehensive study of the mineral requirements for milk production is carried on. This includes studies on the calcium and phosphorus compounds of feeds, and the effect of feeding rations deficient in calcium and phosphorus on the composition of the blood, on the milk yield, on reproduction, and on calcium and phosphorus metabolism in general. The energy requirements of milking cows are determined. A special nutrition barn provides for extensive feeding experiments under carefully controlled conditions.

The transformation of proteins of the feed into proteins of the milk is the subject of chemical research. This involves the identification of amino acids of the

blood, their quantitative separation, and the changes that take place when the blood passes through the mammary gland.

Metabolism of Bacteria

This includes a great variety of work on decomposition as a result of bacterial action, particularly in relation to taxonomic problems and to changes produced in milk by bacterial growth. It includes also studies on the factors promoting and limiting the growth of bacteria, such as the influence of hydrogen-ion concentration, surface tension, salt concentration, and similar factors.

Chemico-Physical Properties of Milk

Investigations are conducted on the chemistry and physics of the heat and rennet coagulation of milk, the conditions that tend to stabilize or destabilize the colloids, the crystallization of lactose, and the oxidation of fats. This work is applied to such dairy problems as the coagulation of evaporated milk in sterilization; thickening of condensed milk; deterioration of butter and milk powder in storage; separation of lactose in condensed milk, ice cream, and in the manufacture of milk sugar; and to the texture and swell of ice cream.

Utilization of Dairy By-products

Methods are being developed for the more economic utilization of various dairy products, such as skim milk, buttermilk, and whey, which are now utilized inefficiently or wasted. Such problems as the manufacture of casein from buttermilk, the separation of the proteins in a soluble form from whey, and more efficient methods of making milk sugar are considered. The work on by-products includes the extension of old and development of new uses for dairy products. Studies are made in cooperation with other bureaus on the possible uses of milk powder, milk sugar, soluble albumen, and concentrated sour milk in the manufacture of confectionery and salad dressing, and in baking.

BUREAU OF BIOLOGICAL SURVEY

The interference of native and introduced rodents and predatory animals with agriculture, horticulture, forestry, and stock raising calls for constant chemical research, to test the effectiveness and cost of application of toxic agents that can be used in control measures. In cooperation with the Bureau of Plant Industry, catnip oil has been developed as a lure for certain predatory animals of the cat family and has been used with much success. In extensive research in cooperation with the Bureau of Chemistry and Soils, an effective poison that may prove to be specific for rats is being developed in experiments with red squill, the toxic product being employed in liquid and powdered form.

A laboratory is maintained in the West by the Biological Survey for the purpose of devising methods for eradicating wild-animal pests, particularly on western stock ranges, where wolves, coyotes, and other predatory animals, and rodents such as prairie dogs, pocket gophers, and ground squirrels destroy livestock and forage. The chief chemicals employed by the Biological Survey and its cooperators in organized campaigns for pest control by means of poisoned baits are strychnine and barium carbonate. As fumigants for the eradication of burrowing animals, carbon disulphide and crude calcium cyanide are extensively used, particularly to complete eradication on areas where most of the rodents have been removed by poisoned baits.

BUREAU OF ENTOMOLOGY

The Bureau of Entomology conducts chemical investigations on arsenical compounds, cyanides, nicotine, petroleum oils, and various other substances, with a view to their utilization in the control of insect pests.

Arsenical Compounds

Arsenites and arsenates are being used in laboratory and field experiments for the control of the codling moth, gipsy and brown-tail moths, grasshoppers, Japanese beetle, alfalfa weevil, cotton boll weevil,

mosquito larvæ, plum curculio, Mexican bean beetle, and many other insects. Tests with coated lead arsenate against the adult Japanese beetle have given very satisfactory results. The larvae of the Japanese beetle in the ground are controlled by mixing lead arsenate with the soil. Experiments in the application of arsenicals by airplane have indicated the usefulness of this method for large crop areas. Investigations on the effect of arsenic upon insect metabolism have yielded information which, it is believed, will assist in the explanation of the toxic action of arsenic on insects. Intensive studies on the toxicology of arsenic and certain other organic compounds have been initiated.

Fluosilicates

Fluosilicates, particularly sodium fluosilicate and calcium fluosilicate, are being investigated as poisons for certain truck-crop insects, the codling moth, and the sugar cane moth borer.

Cyanides

Tests are under way to determine the comparative efficiency of calcium cyanide and other cyanides as greenhouse fumigants. Calcium cyanide is rapidly becoming a standard fumigant for use in greenhouses. The use of hydrocyanic-acid gas for the fumigation of citrus trees in Florida is being studied, special attention being directed to the conditions affecting tree injury. Further experiments are being conducted with this material as an "open-air" fumigant for certain truck-crop pests, and as a soil fumigant for wireworms.

Carbon Disulphide

The treatment of soil infested with larvae of the Japanese beetle with carbon-disulphide emulsion has been extensively investigated, and practical methods for its application have been outlined. This material has been used for the fumigation of balled nursery stock over water, the plants being inverted with their tops under water, where they are not exposed to injury by

the fumigant. Tests are also under way on the rapid volatilization of carbon disulphide for miscellaneous fumigation.

Petroleum Oils

The use of petroleum-oil emulsions, particularly those made from lubricating oils, as contact insecticides for use on fruit and camphor trees is being investigated. Problems concerned with the relative toxicity of various oil fractions, types of emulsifiers, factors which affect the action of the oil under field conditions, and the effect of the oil on the plant have received special attention. Studies have been made in cooperation with the Bureau of Chemistry and Soils on the effect of the size of the oil drops in the emulsion on the toxicity to insects. A formula for the preparation of an effective cold-mixed emulsion has been developed.

Pyridine and Pyrrole Derivatives

In cooperation with the Bureau of Chemistry and Soils, certain groups of pyridine and pyrrole derivatives have been investigated as contact insecticides. Several of these compounds have been found to be highly toxic to insects and hold promise of usefulness in spraying and dusting operations. A systematic study of the toxicity of the compounds in these groups is under way.

Nicotine

Tests with nicotine dusts on truck crops are in progress, and effective dust formulas have been developed. A study of the effectiveness of nicotine dusts under field conditions has resulted in improvements in the preparation and application of these dusts. Laboratory studies of the toxicity of nicotine are in progress.

Pyrethrum

A sodium oleate-oleoresin of pyrethrum spray mixture has been developed as a contact insecticide for use against the Japanese beetle. This material has also given promise in preliminary tests on the Mexican bean beetle and bean leaf hopper.

Paradichlorobenzene

Paradichlorobenzene is largely used for peach borer control, and special attention is being given to the subjects of dosage and tree injury. Further tests with this material as a fumigant against the sweet-potato weevil in seed sweet potatoes have been successful in controlling the insect, but the exact effect of this material on the germinating qualities has not been determined, though some retardation of sprouting is indicated.

Attractants and Repellents

Experiments in the use of volatile chemicals as attractants for the tobacco sphinx moth and Japanese beetle have shown promising results. Several preparations for repelling insects from livestock have been developed.

Other Insecticide Investigations

Studies of many organic compounds are being conducted for the purpose of finding a substitute for the arsenicals. In addition, other organic and inorganic compounds are tested for their toxicity to various insects of economic importance.

FOOD, DRUG, AND INSECTICIDE ADMINISTRATION

The science of chemistry is essential for the development of facts and principles to guide administrative action in the enforcement of the Federal food and drugs act, the insecticide act, the tea inspection act, the naval stores act, the milk import act, and the caustic poison act.

In the enforcement of the Federal food and drugs act, it is essential not only that the existing knowledge of chemistry, bacteriology, pharmacology, toxicology, and medicine be brought to bear on numerous questions involving adulteration of foods and drugs with various ingredients, but also that new facts be ascertained by

scientific investigation and experiment regarding the composition of a particular food product shipped within the jurisdiction of the act and the effect upon health of the specific adulterants found in that product, in order that appropriate action may be taken to protect the public from fraud and from harmful adulterants.

Likewise, in enforcing the insecticide act, it is necessary not only to take into account the established facts of chemistry, entomology, and plant and animal pathology which have a direct bearing on any case under consideration, but also to determine specifically by scientific method what is the exact composition of the particular lot of insecticide material in question and to determine by carefully controlled scientific experiment whether it will kill the insects for which it is sold and whether it will injure the plants on which it is used. Also it is necessary to determine by scientific analysis and experiment what inactive ingredients, if any, may be in each and every shipment of insecticides or fungicides examined under the act.

Food Control Investigations

New methods for the analysis of food products are studied and adapted to meet special needs. Field and laboratory studies are made of the canning of fruits, vegetables, and marine products, and of the methods of producing alimentary pastes, flour, cereals, spices and condiments, vinegar, salad dressings, coffee, dairy products, gelatin, egg products, cacao products, jellies, jams, and other foodstuffs. Similar investigations are conducted on flavoring extracts, beverages, and beverage materials. Fruits, fruit juices, and other natural products, and synthetic chemicals which may be used in the manufacture of extracts, flavors, and beverages are considered also. Authentic flavoring extracts, flavors, beverages, and beverage materials are prepared and analyzed to serve as a basis of comparison for such products on the market. Investigations on the pollution of waters, trade wastes in waters, and radioactivity of waters and drugs are conducted. Methods for the analysis of feeding stuffs are studied, with a

view to the improvement of present methods or the development of new methods to meet changing methods of manufacture. Processes of manufacture of feeds and feeding stuffs are investigated, and many samples of such materials are analyzed to obtain information necessary for their proper control.

Such chemical procedure is supplemented, or in some cases superseded, by microbiological and microchemical investigations. Thus, bacteriological studies are necessary to solve many of the problems arising in the inspection of water, in the pollution and decomposition of oysters, and in the detection of spoiled stock in canned foods.

The ingredients and the condition of many foods and feeding stuffs may best be ascertained by the use of the microscope. To facilitate this work, the administration has developed special methods for examining canned pork and beans to determine unsoundness, for testing flour, for detecting decayed stock in tomato and fruit products, and for estimating the proportion of shells in cacao products and rice hulls in stock feeds.

Coal-tar dyes are analyzed to determine their suitability for use as food colors.

Drug Control Investigations

These investigations fall into four main groups: Chemical, medical, pharmacological, and pharmacognostical.

The chemical work includes research in the field of drug chemistry, the development of methods of analysis of medicinal products, and the examination of samples of drugs and medicines sold in the United States or offered for entry at American ports. Systematic surveys of the various types of preparations on the market are conducted from time to time. The products now being surveyed are anesthetics, antiseptics, ampuls, galenicals, and tablets.

The medical work is in the main confined to an examination of the labeling of medicinal products, to determine whether or not the therapeutic representations made are truthful, in the light of the composition as determined by analysis. The basis of judg-

ment is the consensus of present-day medical opinion on the effect of each ingredient of the preparation.

The pharmacognostical work comprises investigations of crude drugs.

The pharmacological investigations include biological assays of a number of drugs for which no satisfactory chemical methods exist. Among these are digitalis, ergot, epinephrine, and pituitary. Official standards for the various drugs for which the United States Pharmacopœia provides bioassay methods are prepared and distributed. This work was undertaken at the request of the pharmacopoeial revision committee. Among the assay methods recently developed is one for the determination of minute quantities of mydriatic and myotic drugs. Investigations on the physiological effects of small quantities of poisonous substances in foods, such as arsenic on fruits and vegetables that have been sprayed, are in progress almost continuously.

Insecticide, Fungicide, and Caustic Poison Control Investigations

Insecticides, fungicides (including disinfectants), and caustic poisons are analyzed to detect adulterated and misbranded materials, and such investigations as are necessary to bring them into compliance with the provisions of the insecticide act of 1910 and the caustic poison act are conducted.

Naval Stores Control Investigations

Permanent color standards for rosin, prepared by the food, drug, and insecticide administration, accepted by producers and users of rosin, and made the United States standards by congressional action, are now used for grading rosin sold in this country.

Samples of turpentine and rosin are collected, and analyzed or graded, with a view to keeping adulterated and misbranded naval stores from entering the channels of trade.

The naval stores control unit is authorized under the service features of the naval stores act to analyze and grade naval stores of doubtful purity or grade, when

formally requested by an interested person, and at a stipulated cost. If samples are taken from such lots by an official inspector in person, a certificate of analysis or grade is issued. If the sample is not taken by an official inspector, the charge is the same but, instead of a certificate, simply a letter giving the results of the analysis is sent to the person who requested the analysis.

Special Collaborative Investigations

Most of this chemical work is done for the Post Office Department and the Federal Trade Commission. Samples of various preparations sold through the mails are analyzed to obtain evidence to assist the Post Office Department in the prosecution of cases under the fraud order law and to assist the Federal Trade Commission in the prosecution of concerns indulging in unfair trade practices. Products examined are those making claims for the cure of catarrh, diabetes, tuberculosis, pyorrhea, cancer, and other diseases, as well as many making extravagant claims for beauty schemes and fat reducers. Packages sent through the mails which are suspected of containing concealed poisons are examined.

FOREST SERVICE

The chemical research of the Forest Service is confined largely to the chemistry of wood, in both its fundamental and industrial aspects. The work is carried on at the forest products laboratory of the Forest Service at Madison, Wis. Studies are conducted on the chemical composition of wood; products formed by trees, extractive materials in wood; acid hydrolysis of wood; wood preservation; fireproofing of wood; wood working glues; and pulping processes.

The chemical composition of wood is investigated to obtain fundamental information for use in connection with chemical utilization methods. The relations between different constituents, and the location of the constituents in the microstructure are studied.

Microanalytical studies of the nature, location, and development within the tissues of products formed by

trees, such as oleoresin, gums, and sugars, are carried on to gain a better understanding of natural processes so that the production of timber and by-products can be more effectively controlled by forestry methods.

Of all the constituents of wood, the extractive materials are the most variable in composition and quantity. Both their composition and their effect on wood properties are studied.

Chemical research on the acid hydrolysis of wood is practical, being intended to promote utilization of softwood mill waste by the manufacture of alcohol, sugars, cattle feed, or other products by hydrolytic means. Researches in this field also furnish valuable information on the chemical composition of wood.

Physical chemistry is applied in the study of the structure and properties of wood. This includes investigations on the flow of liquids through wood under pressure or high electrical potential, the true specific gravity of wood substance, the electrical conductivity of wood at different moisture contents, and the equilibria of wood and volatile liquids.

In the problem of wood preservation, subjects of inquiry are the toxic powers of wood preservatives; their action on fungi; the facts which determine their penetrating properties; their chemical stability; and their permanence in the wood.

Wood working glues are investigated, with special attention to means of making casein glues more durable on long-continued exposure, and to improved methods of inspecting casein glues for quality.

Pulp processes are carefully studied, with a view to improving existing processes and to developing new methods for increasing pulp yields; and also to ascertain means for economizing on chemicals; to utilize for pulp hitherto unused species, wood wastes, and fiber sources other than wood; to determine the chemical properties of wood and pulps with the object of enhancing paper-making qualities, improving the secondary treatment of pulps in developing special properties, and developing analytical methods; and to discover the causes and means of prevention of various sources of industrial wastes, including the decay of wood pulp, and recovery and economical disposal of waste liquors.

BUREAU OF HOME ECONOMICS

Chemical research supplements the work of the nutrition and textiles divisions of the Bureau of Home Economics.

Food and Nutrition

A study of the relative calcifying properties of a commercial alcohol-soluble extract of cod liver oil and cod liver oil as determined by feeding experiments with rats has recently been completed. The method used is offered tentatively as a means of measuring vitamin D content of foods.

Experiments to determine the vitamin A, B, C, and D content of the outer and inner leaves of head lettuce purchased on the Washington market, and also of two samples of honey, are in progress. All research on vitamin A determination has been designed to give as much information as possible which would help in improving the technique of the method used.

Tables on the proximate composition and fuel value of food materials are being prepared for use in dietary calculations. The figures are derived from a study of data compiled from a large number of sources including published and unpublished material. They will represent as nearly as possible the composition of typical food materials and will provide a basis for reducing some of the errors in dietary calculations.

Textiles and Clothing

The chemical aspects of various textile problems are studied. At present emphasis is being placed upon a series of researches on various phases of home laundering and cleaning. These include investigations on starching and the effect on various textile materials of the temperatures and reagents employed during washing and ironing.

BUREAU OF PUBLIC ROADS

When all vehicles using the highways had steel tires and were drawn by horses, the highest type of improved road was the macadam or stone-surfaced highway.

This type of surface was built of crushed stone spread in two or more courses of uniform thickness over the road-bed and held together by stone dust flushed with water into the crevices between the stones.

The stone dust, as the binding material, was the life of the road. Without it the road would disintegrate into a bed of loose stones. But so long as vehicles had steel tires and moved slowly there was never any lack of the binding dust. If any of it were blown away the loss was soon replaced by the grinding of the steel-tired wheels and the hammering of the horses' hoofs.

With the introduction of the pneumatic-tired automobile these macadam roads rapidly deteriorated. The fast-moving vehicles withdrew the binding dust and blew it away, and their rubber tires so reduced the wear of the stone that the lost binding material was not replaced. Not only were the best roads of the country rapidly destroyed, but travel was made exceedingly uncomfortable by the dust which hung in clouds over all heavily traveled roads.

At this critical moment the chemist offered timely aid to the highway engineer by proposing the use of bituminous materials (tar and asphalt) as a binder instead of stone dust, and as a result of the change the roads were saved and the dust clouds disappeared.

The bituminous road principle has since been developed scientifically and is now used in many types of roads, some of which are suitable for the heaviest modern traffic. The chemical work of the bureau has to do with tests of bituminous materials. The three principal tests for determining the character of bituminous materials are the penetration, viscosity, and float tests. Although these are physical tests, they were developed to a large extent as a result of the efforts of chemists to evaluate the relative characteristics of bituminous materials.

BUREAU OF PLANT INDUSTRY

The work of the Bureau of Plant Industry calls for chemical investigations in many fields. In addition to work of this kind done in the bureau itself, many activities are carried on in cooperation with the

Bureau of Chemistry and Soils, and with other bureaus, State experiment stations, and agricultural colleges.

A number of the investigations in progress in the fruit and vegetable utilization work are primarily chemical. Among these may be mentioned the varietal studies of fruits and vegetables, in which a study of the chemical composition of different varieties is made, to ascertain their possibilities for use in canning, preserving, drying, or the making of various food products. Most of these experiments involve comparison of many varieties of a fruit or vegetable grown under controlled conditions so that the effect of climatic factors upon the composition of the crop as a whole, and also on the chemical composition of the variety is shown. The securing of such information is a necessary preliminary to developing methods of utilization.

On account of the importance of color in determining the marketability of fruits and vegetables and preserved products derived therefrom, chemical investigations on various plant pigments are being made. Information obtained by these studies aids the horticulturist, since, in plants, hardiness, vigor, and resistance to disease are correlated with pigments. This information will also be of service to canners, who have long desired a definite method for standardizing both the raw material and the finished products of their industry.

Researches are being made on the composition of the surface coatings of apples, and on the effect of development, exposure, regional conditions, and storage on the composition of the cuticle. Since these coverings have a direct bearing on the susceptibility of apples to storage injury, these experiments may aid in finding means for the prevention of loss during storage.

Chemistry is utilized in investigations on cereals. Healthy and diseased corn plants are analyzed, to ascertain whether starch and sugar are consumed by smut organisms. Chemical studies are made of the juices of wheat plants to determine the relation of the acidity of the cell sap to disease resistance, and to determine the effect of age and environment on the acid content of the juices. Chemical methods are

used to discover the susceptibility of wheat to the scab fungus; to determine the inheritance of quantity and quality of gluten, and the inheritance of winter hardiness, in wheat hybrids; and to show the effect of different rotations and cultural methods on the protein content of wheat. Many different chemicals have been tested under both field and laboratory conditions in searching for more satisfactory means of killing the common barberry. The nature of the organic nitrogen compounds in cereal grains has been studied, and the effect of various constituents of the soil on these crops has been noted.

Biochemical studies in plant nutrition include a study of the effect of light, particularly variations in the daily light period, on internal changes in the plant. The purpose is to ascertain the nature of the internal processes which are responsible for, or are associated with, initiation of flowering and fruiting and other features of development in response to the daylight period. Attention is given to the effect of variation in supply of different nutrients, especially an insufficient supply, on chemical processes in the plant, such as carbohydrate and nitrogen metabolism.

Biochemical investigations on poisonous plants comprises the determination, isolation, and identification of the poisonous principles.

Chemical studies of sugar plants consist of the determination of sugars and other constituents in both the plant and the juice of sugar cane, sugar beets, and sorgo, together with studies of methods of analysis and studies of special constituents. All this work requires chemical investigations, such as varietal studies, breeding and selection experiments, disease resistance tests, maturity tests, and tests to show the effect of environment, temperature, and soil.

Chemical methods afford the chief means for measuring metabolic processes in plants, consequently chemistry has entered extensively into the various phases of the work in plant physiology.

Studies have been made of the carbohydrate changes occurring in root crops during development and storage, in order to determine the kind of transformation of carbohydrates taking place under different conditions

of storage and also the extent of loss of these food materials from stored roots and tubers through normal processes. This work forms the basis of determining the most favorable conditions of storage.

Investigations are conducted on the chemical changes which take place in the processes of ripening, curing, and fermentation of leaf tobacco; the effects of temperature, moisture, and other external conditions on the progress of these changes; and nicotine content as affected by heredity and environment. Tests are made to disclose the relation of chemical composition to the burning qualities and other properties of tobacco, and to show the specific effects of the several plant nutrients and climate on chemical composition, growth, and properties of tobacco.

Chemical work is done incident to the production of perfume and drug plant crops, dealing with the analysis of essential oils, and drug and related products; with the isolation and identification of their constituents; and with methods of commercial production of such products.

Drying oils obtained from new oil seed crops grown in the United States are analyzed and the possibilities of commercial production and technological application of these oils are carefully considered. Waste products of various industries and crops are studied with a view to the commercial production and utilization of essential oils, fatty oils, extracts, and similar products.

Diseases of plants, fruit trees, and fruits receive critical attention. Chemical methods are used in a study of the poisons or unbalanced conditions that bring about physiological or nutritional diseases; in a study of the disease-producing organisms; in the preparation of culture media; and in the preparation of sprays and dusts. Tests are made of the various fungicides and combinations of fungicides to obtain comparative data on the effect of their fungicidal powers and injurious properties on the host plant.

Chemical studies of culture media and normal and diseased plant juices have been carried on for many years. A scale has been devised for translating the older terms of expressing acidity in a culture medium into the newer hydrogen-ion terms (1922).

Chemical investigations are a factor in various other activities of the Bureau of Plant Industry, such as the study of nematocides proper (effect and application); chemotherapy of plants suffering from nemic plant diseases; chemical sterilization of the soil to destroy its nemic fauna; and chemical treatment of seed for the purpose of freeing them from nemic infestations and of preventing nemic attacks while they germinate.